Childhood Incident Asthma and Traffic-Related Air Pollution at Home and School

ONLINE DATA SUPPLEMENT

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METHODS

Some results have been reported previously (McConnell et al. 2007; Shankardass et al. 2009) . A new Children's Health Study (CHS) cohort was recruited in 2002-2003 from schools in 13 southern California communities. Nine communities were the same as in the original Children's Health Study cohorts, and four were new. All students present in 2002-2003 in all kindergarten and first grade classrooms in participating schools were given a questionnaire and informed consent to take home for parents to complete. The study population of 5349 included 5341 children with a questionnaires and parental informed consent submitted at study entry, as described previously (McConnell et al. 2006). Eight additional participants with a questionnaire submitted at study entry were included in this analysis after later obtaining informed consent. Information on demographic characteristics which were asked repeatedly in yearly questionnaires has been updated for this analysis.

Asthma covariates

From the parental questionnaire at study entry, the child's history of allergy was defined based on a history of hay fever or a problem with sneezing or runny or blocked nose when the child did not have a cold. Race and ethnicity included non-Hispanic white, Hispanic, African American, Asian, and other/unknown. Other relevant information included a parental history of asthma, maternal smoking while pregnant with the child, household income and responding parent's education, health insurance for the child, and current second-hand tobacco smoke exposure in the child's home at the time of the questionnaire (SHS). Housing characteristics included pests in the home during the previous year, a dog or cat in the home, mold or mildew on household surfaces, and an indoor source of NO_2 (a pilot light or gas heater). Heavy exposure to smoke from a series of wildfires in several study communities in 2003 was based on six or more days of smelling smoke indoors (Kunzli et al. 2006).

Pollution exposure

The 2003-2004 average ambient O_3, NO_2, PM_{10} and $PM_{2.5}$ measured at each community monitor were assigned to all children in the community, because there was little year-to-year variation within individual communities, based on these data and on historical data for 9 of the 13 study communities that have been monitored since 1994 as part of the exposure assessment for previous CHS cohorts (Gauderman et al. 2004). The 10 AM to 6 PM O_3 exposure used for health analyses was highly correlated with the average of the daily 1-hour maximum.

Participant residence and school addresses were standardized and their locations were geo-coded to 13 m perpendicular to the side of the adjacent road, using the Tele Atlas database and software (Tele Atlas, Inc., Boston, CA, www.na.teleatlas.com). Distance to the nearest major road was estimated using ESRI ArcGIS Version 8.3 (ESRI, Redlands, CA, www.esri.com). A major road was defined based on functional classification by the California Department of Transportation as a freeway (with limited access) or other highway (typically with heavy traffic volume), or a major or minor arterial thoroughfare. Each direction of travel was represented as a separate roadway, and the shortest distance was estimated from the residence to the middle of the nearest side of the freeway or major road. We included in the analysis only children with addresses that could be geo-coded accurately. Specifically, only residential addresses for which the Tele Atlas geocoding software assigned its highest quality match code were included. These addresses were located on the correct side of the street with their relative position between cross streets determined by linear interpolation of residence number between the nearest intersections. Almost one third (104) of the 340 children who were excluded because the address could not be geo-coded was located in a single community (Lake Arrowhead) with winding streets and long distances between intersections that made it difficult to interpolate accurately to a geo-coded location.

Residential and school address distance to a freeway were categorized as <500 m, 500-999 m, 1000-1499 m, and >1500 m, based on the distribution of the residences of participants and results from a previous CHS cohort that have shown respiratory health associations on this spatial scale (Gauderman et al. 2005; Gauderman et al. 2007). Distance to the nearest major road (including freeways) was categorized as <75 m, 75 to 150 m, >150 m to 300 m, and >300 m, based on the markedly increased exposure and risk of asthma within 75 m of large roadways in previous studies (including this cohort at study entry), which decreased to background levels by 150 to 300 m (Gilbert et al. 2005; McConnell et al. 2006; van Vliet et al. 1997; Venn et al. 2001; Zhu et al. 2002). Annual average daily traffic volumes were obtained from the California Department of Transportation Highway Performance Monitoring System (CalTrans 2002). Our previous estimates of traffic volumes (McConnell et al. 2006) were updated to reflect changes in volume and traffic patterns during the follow-up period from 2003 to 2005. Using previously described methods, the traffic volumes were transferred from the Department of Transportation roadway network to the TeleAtlas networks (Wu et al. 2005). The link-based traffic volumes were used to generate maps of traffic density with 10 x 10 m resolution using the ARCInfo Spatial Analyst software. Traffic density maps are created with 150 m circular search radius that produces densities decreasing by ~90% between the edge of the roadway and 150 m away (perpendicular) from the roadways, which is consistent with the characteristics observed previously in Los Angeles (Zhu et al. 2002). Identical mapping procedures were used in all the communities so that the results were comparable across communities. Traffic density generally behaves like an inverse-distance weighted traffic volume, except that it specifically considers intersections and multiple roadways more accurately. Therefore, these density values provide a relative indication of which residence locations are likely to be most exposed to traffic activity and, as such, are relative indicators (with arbitrary units) of proximity to traffic volume.

Exposure to local traffic-related pollutants at homes and school was estimated from CALINE4 dispersion models that incorporate distance to roadways, vehicle counts, vehicle emission rates, wind speed and direction, and height of the mixing layer in each community (Benson 1989). Separate estimates were made for the contribution of local traffic on freeways and on all other roadways to concentrations of several pollutants, including carbon monoxide, nitrogen dioxide, total oxides of nitrogen, elemental and organic carbon and PM_{10} and $PM_{2.5}$**.** These estimated pollutant exposures should be regarded as indicators of annual average incremental increases due to primary emissions from local vehicular traffic on top of background ambient levels. Modeled total oxides of nitrogen (NO_x), for example, which we used to evaluate associations with asthma, represented only the effect of the incremental contribution of local traffic to a more homogeneous community background concentration of NO_x that included both primary and secondary pollution resulting from long range transport and regional atmospheric photochemistry. This metric was highly correlated with other pollutants estimated by CALINE4 (R>0.94). Therefore, modeled NO_x represented primary local NO_x from vehicular traffic, these other highly correlated pollutants in fresh traffic exhaust, and probably other pollutants for which we did not estimate exposures. It was not possible to distinguish the effects of these different pollutants from each other. Therefore, this mixture of pollutants is referred to as TRP (traffic-related pollutants) for brevity.

Statistical analysis

Although there was substantial variation within communities in traffic related exposure at residences, the analyses of effects on asthma were conducted using random effects for community and school, in order to exploit the full range of traffic exposure across all communities. We conducted sensitivity analyses in which traffic metrics were centered on the mean traffic exposure in each community, in order to evaluate the possibility that community characteristics associated with asthma might ecologically confound the effects of residential traffic. Thus, the traffic exposure $X_{dev} = X_{ijl}-X_j$ was substituted for X_{ijl} in equation (1) in the main text of this manuscript, where X_{ijl} was the individual traffic exposure and X_j was the average traffic exposure in community j. However, the effect estimates of residential exposure derived from these exposure estimates centered on the community mean were very similar to estimates from the uncentered analysis (data not shown). Adjusting the individual level estimate for the community mean (eg. mean residential TRP in community j) also did not substantially change the effect estimate for the individual level exposure. Therefore, the uncentered individual and school estimates are presented (except for analyses in which school and residential traffic metrics are adjusted for each other, as described in the main text of this manuscript).

RESULTS

The correlations of the cruder residential traffic metrics ranged from weak, e.g. -0.29 for distance to nearest freeway with TRP, to moderate (-0.61 for freeway distance with freeway TRP; Table E-1 above the diagonal). There was an approximately similar range of correlations of school metrics (Table E-1 below the diagonal). Traffic density was positively correlated, and distance from freeways and other major roads was inversely correlated, with TRP metrics at both homes and schools, as expected.

We examined the associations of asthma with different ambient air pollutants measured at the community central site, adjusted for total TRP at schools and homes, to see if the pattern of effects differed from that observed after adjustment for non-freeway TRP in Table 5. The results were qualitatively similar, as the association of central site NO_2 with asthma was attenuated by adjustment for total TRP (Table E-2). Adjusting for the measured central site pollutants resulted in small increases in the strength of the association with total TRP at homes and asthma, compared to the unadjusted hazard ratio for total TRP of 1.32 shown in Table 3. The estimated effect of total TRP at homes remained significant after adjustment for total TRP at schools and for each central site measured pollutant.

We examined the distribution and estimated effects of traffic density and distance to freeways and to major roads (including freeways). Three schools had zero traffic density within 150 m, because all traffic metrics were estimated from the center of the classroom buildings and there were no roads within 150 m (Table E-3). There were associations of asthma that were weakly positive with traffic density and negative (protective) with distance to freeways and major roads (Table E-4), but these were not statistically significant. There was an increased risk of asthma (also not statistically significant) among children living within 75 m of a major road (HR 1.43; 0.86, 2.37; Table E-5), but the association with school within 75 m was weak. There was little consistent pattern of association of asthma with other residential or school categories of distance to the nearest freeway up to 1500 m. There was an anomalous increased risk associated with living between 1000 and 1499 m of a freeway (HR 1.76; 95% CI 1.07, 2.91) compared with >1500 m, an association probably due to this freeway distance category having the highest mean levels and distribution of estimated TRP from non-freeway roads (data not shown).

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Table E-1: Rank correlation of different traffic metrics (residential correlations above the diagonal and school correlations below)[a]

Traffic Metrics	Total TRP	Freeway TRP	Non-Freeway TRP	Density	Distance to Freeway	Distance to Major Road
Total TRP		0.94	0.85	0.49	-0.55	-0.52
Freeway TRP	0.97		0.64	0.34	-0.61	-0.42
Non-Freeway TRP	0.83	0.70		0.58	-0.29	-0.52
Density (150m)	0.51	0.39	0.69		-0.31	-0.60
Distance to Freeway	-0.53	-0.57	-0.41	-0.42		0.47
Distance to Major Road	-0.53	-0.47	-0.65	-0.55	0.54	

[a]All correlations were statistically significant ($p<0.05$).

Table E-2: Mutually adjusted associations of new onset asthma with community central site pollutant measurements and total TRP at home and school[a]

Central Site Pollutant	HR (95% CI) for Ambient Pollutant Adjusted for TRP at Home and School[b]	HR (95% CI) for Home TRP, Adjusted for School TRP and Ambient Pollutants[b]	HR (95% CI) for School TRP, Adjusted for Home TRP and Ambient Pollutants[b]
NO_2	1.79 (0.91-3.52)	1.36 (1.05-1.78)**	1.10 (0.80-1.51)
PM_{10}	1.46 (0.67-3.19)	1.39 (1.06-1.83)**	1.21 (0.90-1.62)
$PM_{2.5}$	1.52 (0.78-2.94)	1.41 (1.09-1.82)*	1.15 (0.86-1.56)
O_3	0.86 (0.41-1.82)	1.40 (1.08-1.42)*	1.21 (0.91-1.61)

[a]Mutually adjusted across each row (ie. effect of each community pollutant was examined separately in a model including both home and school TRP)

[b]Hazard ratio (95% confidence interval) for each central site pollutant across the range of exposure in the 13 communities (23.6 ppb for NO_2, 43.9 μgm/m^3 PM_{10}, 17.4 μgm/m^3 $PM_{2.5}$, and 30.3 ppb for 10 am to 6 pm O_3). All models were adjusted for race/ethnicity and for baseline hazards strata of age at study entry and sex with random effects for community and school. Household total TRP was deviated from school, scaled to the IQR for home NOx (20.9 ppb from Table 2).

*P<0.01; **P<0.05

Table E-3: Distribution of annual average residential and school traffic density and distances to major roads

		Mean	Median	IQR	Min	Max	Range
Residential traffic	Traffic density	48.3	14.1	54.4	<0.0001	1,029	1,029
	Distance (in m) to freeway	1,912	1,193	1,843	24	18,210	18,186
	Distance (in m) to major road	433	262	395	0.02	7,516	7,516
School traffic	Traffic density	40.7	21.1	50.5	0	349.8	349.8
	Distance (to m) to freeway	2103	1393	1732	106	15252	15146
	Distance (in m) to major road	506	319	483	19	2069	2050

Table E-4: Association of new-onset asthma with traffic density and distance to major roads and freeways at home and school

	Home		School		Combined[b]	
Traffic-related exposure[a]	HR[c]	(95% CI)	HR[c]	(95% CI)	HR[c]	(95% CI)
Traffic Density	1.07	(0.99-1.15)	1.07	(0.93, 1.24)	1.09	(0.99-1.19)
Distance to major road	0.88	(0.72-1.08)	0.83	(0.65-1.05)	0.85	(0.68-1.07)
Distance to freeway	0.89	(0.76-1.04)	0.93	(0.81-1.08)	0.89	(0.76-1.05)

[a]Scaled to the IQR at homes for each metric (from Table 2)
[b]Combined weighted for time at home and school
[c]Hazard ratio (95% confidence interval, adjusted for race/ethnicity and for baseline hazards strata of age at study entry and sex) with random effects for community and school.

Table E-5: Association of distance categories from freeway and major road at home and school with new onset asthma.

	Residential Distance				School Distance			
	N[a] (%)	N[b]	IR[c]	HR[d] (95%CL)	n[a] (%)	N[b]	IR[c]	HR[d] (95%CL)
Distance to Freeway[a]								
≥ 1500m	43 (4.1)	1046	15.6	1.00	52 (4.8)	1090	18.3	1.00
1000 - 1499m	24 (6.6)	366	26.3	1.76 (1.07-2.91)	16 (5.1)	315	20.0	1.09 (0.62,1.93)
500 - 999m	27 (5.9)	456	23.4	1.58 (0.97-2.57)	26 (5.5)	471	20.9	1.14 (0.71,1.83)
0 - 499m	26 (4.1)	629	16.1	1.06 (0.65-1.74)	26 (4.2)	621	16.7	0.93 (0.57, 1.50)
Distance to Major Road[a]								
≥ 300m	50 (4.6)	1096	17.6	1.00	73 (4.8)	1510	18.6	1.00
150 - 299m	30 (4.7)	641	18.4	1.06 (0.67-1.67)	21 (4.4)	477	17.2	0.92 (0.56,1.50)
75 - 149m	18 (4.4)	407	17.2	0.99 (0.58-1.71)	17 (5.3)	324	20.2	1.04 (0.61,1.78)
< 75m	22 (6.2)	353	24.3	1.43 (0.86-2.37)	9 (4.8)	186	19.7	1.13 (0.56-2.29)

[a] Number of cases
[b] Number of subjects in stratum
[c] Crude incidence rate per 1,000 person-years
[d] Hazard ratio (95% confidence interval) adjusted for race/ethnicity and for baseline hazards strata of age at study entry and sex; all models for home metrics have community and school random effects

Table E-6: Comparison of baseline characteristics between children included in the study and those excluded due to loss to follow-up or an address that could not be geo-coded.

	Study Population (N=2,497)	Excluded from the study (N=875)
Characteristic	N[a] (%)	N (%)
Age at Entry		
<6 Years	496 (19.9)	203 (23.2)
6 Years	1178 (47.2)	392 (44.8)
>6 Years	823 (33.0)	280 (32.0)
Race/ethnicity		
Hispanic white	1380 (55.5)	532 (61.7)
Non-Hispanic White	905 (36.4)	258 (29.9)
African-American	77 (3.1)	43 (5.0)
Asian	97 (3.9)	9 (2.2)
Other/unknown	38 (1.5)	10 (1.2)
Gender		
Female	1307 (52.3)	435 (49.7)
Male	1190 (47.7)	440 (50.3)
Health insurance	2135 (85.5)	696 (79.5)
Household Income		
≤14,999	329 (14.1)	204 (25.5)
15,000-49,999	714 (30.6)	281 (35.1)
>50,000	1292 (55.3)	316 (39.4)
Parental Education		
Less than high school	508 (21.4)	262 (32.3)
At least High School	452 (19.1)	200 (24.7)
Some College	850 (35.9)	250 (30.9)
College and above	560 (23.6)	98 (12.1)

[a]Numbers may not add up to the total in some subgroups due to missing data